

## Settling the West: 50 000 years in a changing land

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### Abstract

Australia was first colonised more than two thousand human generations ago. In this paper we show how, over this period, ancestors of Western Australia's Aboriginal peoples adapted to changing environments, in tropical savannahs, deserts, woodlands, forests and coastlines. Throughout this history, there is evidence for intra-regional genetic and economic continuities, and exchanges and dynamism in religion, language and art. These relationships are remarkably well-documented in Western Australia, which features many of the oldest sites on the continent. The evidence reviewed here derives from the Kimberley, Western Desert, Pilbara and South West. Each region contains at least one site first occupied c. 50 000 years ago, and numerous other sites first occupied in the late Pleistocene. We describe the archaeological evidence for the early development of a range of complex modern behaviour from each region, including symbolic behaviour, information exchange, ground-stone technology, and ecosystem engineering. We also address the apparent tension between regional continuity and inter-regional contact and exchange.

**Keywords:** Archaeology, Late Pleistocene, Holocene, Western Australia, Aboriginal people

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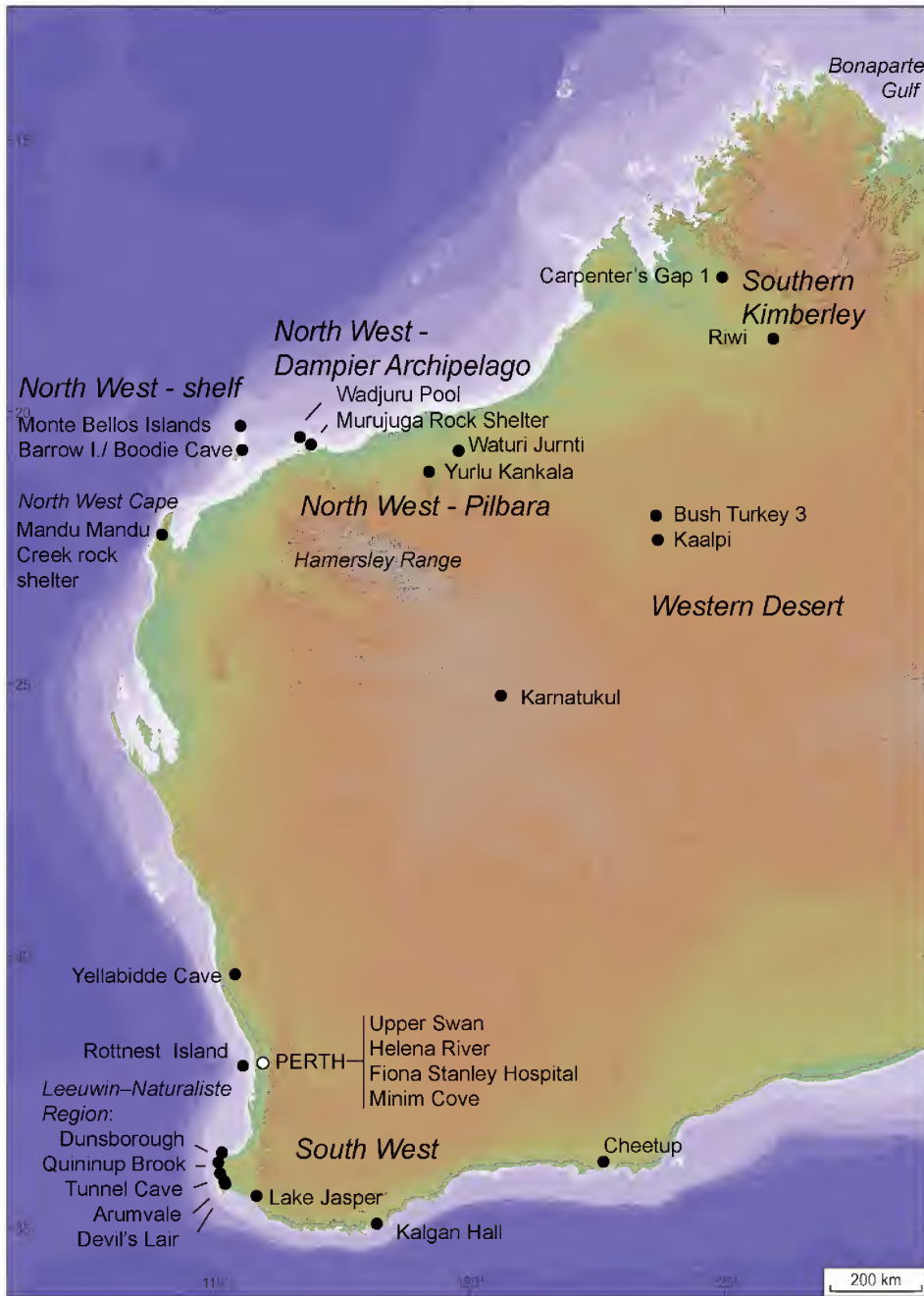
### INTRODUCTION

Archaeological research across Western Australia demonstrates Aboriginal people have occupied all of the State's diverse biomes, spanning tropical, desert and temperate regions, for more than 50 000 years (Turney *et al.* 2001; Morse *et al.* 2014; Veth *et al.* 2017; Balme *et al.* 2018b; McDonald *et al.* 2018a). This remarkable coverage has implications for the timing of human dispersal across the world and the processes by which humans settled and managed new environments, including their social interactions across vast landscapes (Veth *et al.* 2011). The evidence for these achievements in Western Australia includes symbolic behaviours which have parallels in contemporary societies, including personal ornamentation, rock art, and long distance movement of exotic items (marine shell), and indicates the development of regional differentiation and identity persisting for much of the period of human occupation (Dortch 1979; Morse 1993a; Morse *et al.* 2014; O'Connor *et al.* 1998; McDonald *et al.* 2018a; Balme & O'Connor 2018; Balme *et al.* 2018, 2019). Genographic research supports the inference that distinct but interconnected regional populations emerged early in the history of the first Australians (Malaspinas *et al.* 2016). In this review, we aim to show that these regional signatures relate to negotiation of wide-spread, complex exchanges

between autonomous groups who maintained long-distance connections at the same time as affirming strong affiliations to territory: a combination that was essential to the considerable achievement of occupying so many challenging terrains for this period.

As a global counterpoint to the dispersal of anatomically modern humans out of Africa, Western Australia provides a unique sampling point for adaptations of people to both familiar and unique landscapes (Veth *et al.* 2017). Evidence of long occupation from north to south of the State confirms the long-held view that ancestral Aboriginal peoples successfully crossed and settled a series of widely differing environments and adapted to endemic regional biodiversity on the way. At present, the wider Australian evidence does not support a preference for any of the possible colonising routes through various parts of the Indonesian–Malaysian archipelago (Bird *et al.* 2018). Nor does the evidence allow identification of the colonisation pathways within Australia. However, the oldest sites in each region of Western Australia appear to have been first occupied at about the same time, c. 50 000 years ago (50 ka), across almost 20 degrees of latitude, and from desert to coast, suggesting that whatever the pathways, colonisation was rapid and highly flexible.

The “colonising” narrative contrasts with most Aboriginal traditions of Indigenous origins, but there is common ground. Although the knowledge base differs, both scientific and traditional interpretations agree on the longevity of both cultural connections to landscapes



**Figure 1.** Selected regions in Western Australia—southern Kimberley, North West (with sub-regions), Western Desert, South West—and archaeological sites mentioned in the text.

and changes in Aboriginal cultures within Australia. However, the nature of the archaeological record limits our present discussion to technological innovations, symbolic communication (including art, ornamentation and the materials used), and use of the environment for resources. We discuss these different lines of evidence under headings for each of four biogeographic zones reviewed here: Southern Kimberley; North West (divided into three sub-regions); Western Desert; and South West (Figure 1). These regions collectively cover more than 50% of Western Australia. They have been subject to archaeological investigation for some decades, but particularly in the last five years with several on-going projects—hence the present review.

## SOUTHERN KIMBERLEY

The traditional lands of Bunuba and Gooniyandi people are in the southern Kimberley of Western Australia. In the monsoonal tropics, the area is not as influenced by the moist monsoonal belt as the northern part of the Kimberley (Bureau of Meteorology 1996). The main topographic features in the southern part of this region are limestone ranges, including the Oscar, Napier, Emanuel and Lawford Ranges, which are relicts of a Devonian reef (Playford *et al.* 2009). In these reef systems caves and rockshelters have formed and preserve evidence, including hearths, artefacts and plant and animal remains, of Aboriginal people's use of the area for about 50 000 years (Balme *et al.* 2019).

Abundant evidence, including rock art, open campsites, stone quarries, and landscape features with religious significance, documents diversity in the long-term use of the area. This evidence provides a story of innovation, landscape learning, flexible use of a sometimes-difficult environments and, over time, the importance of wide social networks in people's lives. The earliest such evidence in the region comes from Carpenter's Gap 1 (CG1) in the Napier Range dating to between 51 and 45 ka (51 000 to 45 000 years; Maloney *et al.* 2018; Figure 2A) and Riwi, in the Lawford Range, with first occupation dating to between 46.4 and 44.6 ka (Wood *et al.* 2016; Figures 1, 2B). CG1 is less than two kilometres from the Lennard River and about eight from Windjana Gorge, which today usually maintains pools of water even in the dry season. Riwi is further south and closer to the desert boundary. At Riwi there is no permanent source of freshwater, but a small creek runs in front of the cave during the wet season.

At the time of first human occupation of these two sites, the climate was more humid than today (Fitzsimmons *et al.* 2013) and favourable for human occupation. People used these sites opportunistically, exploiting animals from the surrounding savannah on the rocky hill slopes and sand plains, and at CG1, from freshwater sources. Fruits and seeds from trees growing in monsoonal rainforest pockets in seasonal gullies in the limestone were particularly targeted for plant foods (Balme *et al.* 2019; Maloney *et al.* 2018). More fragile artefacts such as those made of fibre or other organic materials are not preserved in the oldest sediments but the presence of ochre fragments and, at CG1, a slab of painted rock at 40 000 years ago (O'Connor & Fankhauser 2001) indicates early symbolic activities.

Of particular note is the presence of a flake from an edge-ground axe found at CG1 associated with dates of 49–44 ka (Hiscock *et al.* 2016; Figure 2C). Evidence for edge-ground axe use is found in the oldest deposits of several other sites across northern Australia (e.g. Madjedbebe, on the edge of the Arnhem Land Plateau in the Northern Territory, where they are found in contexts older than 50 ka; Clarkson *et al.* 2017) but is not found in the southern two thirds of the continent, or indeed anywhere else in the world apart from Japan (Takashi 2012), until the Holocene (Balme & O'Connor 2014). Their consistent presence in the deepest layers of Pleistocene sites of northern Australia suggests their role as a colonising technology, perhaps for use on what would have initially been hardwood savannah trees. The restricted distribution suggests the existence of social links or cultural adaptations across northern Australia that did not penetrate to the south.

Between the earliest phases of occupation at these two sites and the Last Glacial Maximum (LGM, c. 22–18 ka), evidence for occupation is sporadic at both CG1 and Riwi (Maloney *et al.* 2018; Balme *et al.* 2019). There is little evidence of changing lifestyles during this period with people continuing to procure food primarily on the sand plain and in the rocky ranges at both sites with plants from monsoon rainforest pockets continuing to be economically important (Balme *et al.* 2019; Maloney *et al.* 2018). Considering the position of the sites on the

edge of the present arid zone, we had expected that like many arid-zone sites (e.g. Morse 1988; O'Connor *et al.* 1999; Przywolnik 2005; Veth *et al.* 2014, 2017), evidence of occupation of sites in the southern Kimberley would be much reduced during the LGM, a period of reduced precipitation across Australia. However, this is not the case at either site. At CG1, the evidence suggests that people made greater use of freshwater sources, including fish and shellfish during the LGM (Maloney *et al.* 2018). Sponge spicules, sedges and diatoms increase in abundance at CG1 during the LGM (McConnell & O'Connor 1997; Wallis 2001) suggesting that, while resources on the plains may have been reduced, at least at times, water was available in the nearby river and gorge system. This suggestion is supported by the interpretation by Denniston *et al.* (2013) of a speleothem record from Ball Gown Cave, near Carpenter's Gap, indicating an active monsoon across the western Kimberley during the LGM between 24 and 22 ka. The same observations may also explain the strong record of occupation at Riwi during the LGM, despite the lack of permanent freshwater (Balme *et al.* 2019). These findings not only highlight the variation in LGM in different parts of Australia but are also consistent with opportunistic use of the landscape during periods of climate change.

During the Holocene, there is an increase in occupation intensity mainly indicated by the greater quantities of archaeological materials discarded at both sites. In this period, there is better preservation of organic materials, such as wood shavings and fibre (Balme *et al.* 2019; Maloney *et al.* 2018), illustrating the variety of technologies used by the sites' occupants. There is also evidence of more systematic use of the area, indicating better knowledge of the landscape. For example, amongst the higher number of re-touched stone tools at both sites is a greater selection of high-quality exotic stone for tool making, especially at CG1 (Maloney *et al.* 2018).

Landscape knowledge is supported by evidence for wider social networks. This is particularly demonstrated by the presence of 55 beads made from scaphopod shellfish recovered from levels dated at 9–2 ka from all five sites excavated in this area (Balme & O'Connor 2018; Balme *et al.* 2018; Figure 2D). Although isolated fragments of marine shells have been found in Pleistocene deposits at north-western sites 100–200 km from the coast at the time of the beads' deposition, the consistent presence of beads manufactured from a single species at sites up to 500 km from their original source at this time, suggests long-distance social networks were well established by the early Holocene.

At about 1 ka, the distinctive leaf-shaped, bifacial, pressure flaked Kimberley points appear in the archaeological record (Maloney *et al.* 2014) and continued to be made up to the present. Although the presence or absence of serrations along their edge can vary, the manufacture of these artefacts prior to the arrival of Europeans was confined to the Kimberley, suggesting a Kimberley cultural identity within which were several language groups (McGregor 1988) and other cultural alliances as represented in differences in rock art motifs (e.g. Layton 1992; Taçon *et al.* 2003; O'Connor *et al.* 2013; Akerman 2016) across the region.





**Figure 2.** Selected sites and artefacts mentioned in the text: A. Carpenter's Gap, Southern Kimberley, B. Flake from an edge-ground axe at Carpenter's Gap (Hiscock *et al.* 2016), C. Hearths revealed in excavation walls at Riwi, dating from c. 47 ka to 6 ka, D. Scaphopod bead dated to the Holocene from Riwi, E. View of the cliffs containing Boodie Cave on Barrow Island, F. Scaphopod bead dated >10 ka from Boodie Cave, G. Shell bead dated c. 34 ka from Mandu Mandu Creek rockshelter, Cape Range (Morse 1993b), H. Excavations at Yurlu Kankala, Gorge Range, northeastern Pilbara (Morse *et al.* 2014), I. Stone circles interpreted as hut bases in the Dampier Archipelago, dated c. 8 ka (McDonald & Berry 2017), J. Excavations at Karnatukul, Western Desert (McDonald *et al.* 2018b), K. Backed artefact dated >40 ka, from Karnatukul, L. Calcarenite formations overlying palaeo-sol containing artefacts, dated c. 27 ka at Rottnest Island (Dortch & Dortch 2019), M. Beads made on macropod fibulae from Devil's Lair (photo: A. Carson), and N. Hearths dating from 21–13 ka revealed in excavation walls at Tunnel Cave. Scale bars for artefact images are 5 mm.



## NORTH WEST—COAST AND CONTINENTAL SHELF

There is little doubt that the island-foraging settlers dispersing through Wallacea and into Australia had well-developed maritime economies and technologies and were adept at exploiting marine resources backing onto sub-tropical hinterlands. Less known were the 'maritime deserts' south of the Kimberley, where highly productive coastal resource areas were backed by arid rangelands comprising spinifex plains, ancient limestone pavements, dune fields and piedmont uplands. This scenario describes a large part of the State's current littoral zone. At the time Australia was colonised, c. 65–55 ka (Clarkson *et al.* 2017), the expansive coastal plains of the North West Shelf extended over 100 km from the current coastline to as little as 12 km from the steeply dipping shelf off North West Cape (Morse 1993a). This unique coastal configuration provides a rare opportunity to investigate early and ongoing marine adaptations by Aboriginal people in the first 50 ka of coastal occupation of the north (Veth *et al.* 2017; cf. Brooke *et al.* 2017; Morse 1988).

The main study sites of Barrow Island and the Montebello Islands on the North West Shelf lie in the northern Carnarvon bioregion (Figure 1; Moro & Lagdon 2013; Veth *et al.* 2014). The limestone islands provide shelters and caves with excellent preservation for archaeological assemblages (Veth *et al.* 2007). The climate is arid with 300 mm of variable summer and winter rainfall (Kendrick & Mau 2002). Boodie Cave, on the north-western coast of Barrow Island, is optimally positioned near the edge of the Australian continental shelf to infer past use of the drowned coastal plains. The exceptional preservation offered by caves and shelters in limestone substrate has provided a range of significant finds from rockshelter sites on Cape Range and Barrow and Montebello Islands:

- a) Some of the earliest evidence for consumption of dietary shellfish outside of Africa (coeval with Borneo and Timor Leste);
- b) Early evidence for a mixed coastal and arid plains fauna as a maritime desert adaptation;
- c) Transport of dietary and utilitarian shellfish species c 15 km over the emergent continental shelf;
- d) Pleistocene shell beads from personal adornment (e.g. hair, head, wrist or ankle ornaments) and manufactured shell tools (at both Boodie Cave and Mandu Mandu Creek rockshelter; Morse 1993b; Figures 2E–G);
- e) Ongoing use of marine species from before and after the LGM; and
- f) Marine and terrestrial species increasing significantly with proximity of the sea.

Boodie Cave (Figure 2E) registers first human occupation between 51.1 and 46.2 ka, consistent with the majority of other early dated assemblages across northern Australia (Clarkson *et al.* 2017; Veth *et al.* 2017). The cave has evidence for repeated occupation, with a discontinuity straddling the LGM, and then abandonment by 6.8 ka when the island becomes separated from the mainland (Veth *et al.* 2017). This

abandonment coincides with that for the nearby Montebello Islands (first occupied at c. 30 ka) and is a likely function of distance offshore and the diminished carrying capacity of the islands (Veth *et al.* 2007).

By 42 ka coastal foragers collected and transported four taxa of shellfish from mangrove, mudflat and rocky substrates up to 15 km over the coastal plain (Veth *et al.* 2017). Whereas three (*Terebralia*, *Tellina* and *Nerita*) are dietary, the fourth taxon (*Melo* sp.) is a common robust much larger gastropod used for water carrying, ornamentation and shell artefact production (Balme & Morse 2006). *Nerita*, *Tellina* and *Terebralia* could have been safely transported in wet clumps for later consumption at Boodie Cave (Veth *et al.* 2017).

Boodie Cave also contains many modified shell fragments including dentate pieces likely to have been used for marine mammal butchering, chisels and polished edge scrapers. The presence of shell tools is expected given the lack of hard rocks in the vicinity. Twenty-two fragments of Tusk shell (scaphopod) with consistent wear patterns probably served as personal ornaments such as beads in a necklace (Figure 2F). These beads are directly dated as > c. 10 ka.

Prior to the LGM, the terrestrial fauna from Boodie Cave was dominated by arid zone species, including the spectacled hare wallaby (*Lagorchestes conspicillatus*) and euro (*Macropus robustus*), which may have been speared and consumed by small hunting parties (Veth *et al.* 2017). With rising sea levels and a closer coastline, the post-LGM diet expanded significantly to include 40 molluscan and 13 terrestrial species. The latter comprise largely small-to-medium game consistent with foraging by family groups. Early Holocene assemblages are rich and contain marine faunal remains including fish, turtle, marine mammal, crocodile, crab and sea urchin. A similar, though more recent, history is well documented at rockshelter sites on the western coastal margin of the North West Cape (Morse 1993a,b; Pryzwolnik 2005).

### Productivity of the coastal zone before current sea levels

The early dietary shellfish assemblages from Boodie Cave, and recent cores capturing estuarine shellfish at the LGM within the present Bonaparte Gulf (Ishiwa *et al.* 2016) increasingly lend support to models for productive coastal zones during times of sea level change (Ward *et al.* 2015). The prevalence of the estuarine gastropod *Terebralia* in these assemblages, dating from 42.5 ka until the abandonment of Barrow Island, indicates utilisation of mangrove habitats. The early appearance of dietary shellfish in the Boodie Cave assemblages and their presence until abandonment of the island supports our modelling for continuing productivity of the Pleistocene coastline for coastal foragers (d'Alpoim Guedes *et al.* 2016; Manne and Veth 2015; Ward *et al.* 2015).

Recent analysis from John Wayne Country Rockshelter (JWCR), a perched shelter several kilometres from Boodie Cave (Ditchfield *et al.* 2018), also shows that during the Pleistocene mangrove resources were available and transported up to 10 km inland, becoming especially abundant during the 'Big Swamp' phase of the early Holocene. These patterns accord well with the nearby

Barrow Island sites and a suite of rockshelter and open sites analysed on Cape Range to the South West (e.g. Morse 1993a, b, 1999) and from the Pilbara maritime provinces to the east (e.g. McDonald & Berry 2017). At JWCR crustaceans and marine molluscs from mangrove habitats were most intensively discarded between  $10\,759 \pm 880$  to  $8588 \pm 1227$  cal. Before Present (BP; Demuro *et al.* 2019). This age range is earlier than many sites on Cape Range (Morse 1999; Veth *et al.* 2014) but overlaps with dates for the Dampier Archipelago (McDonald & Berry 2017). At the regional level this demonstrates that Aboriginal people exploited productive mangrove ecosystems as sea levels rose towards Barrow Island and beyond. These data do not support notions that rapid sea level rise (including melt-water pulse events) significantly diminished marine productivity (O'Connell & Allen 2012). When combined with earlier coastal assemblages from the region (e.g. Morse 1999; Przywolnik 2005; Veth *et al.* 2017), we conclude that the JWCR record represents a continuation of a much older coastal economy which integrated marine resources from Pleistocene coastlines with those from the arid coastal plains on the now drowned continental shelf.

These findings allow us to entertain new levels of maritime capabilities for modern humans dispersing along the southern arc from Africa, through southern Asia across the islands of Wallacea to Australia (Bird *et al.* 2018; Norman *et al.* 2017). The presence of dietary shellfish from the earliest occupation units of Boodie Cave, and from karstic sites to the north including East Timor and Borneo (Barker 2013; O'Connor *et al.* 2011) provide irrefutable evidence for maritime competencies at the end of the Southern Dispersal Route (Kealy *et al.* 2016). Remarkably the early colonists of the now-submerged shelf of Greater Australia did not turn their back on the sea or remain coastally tethered, but instead rapidly adapted to the marsupial fauna and arid zone plants of the extensive maritime deserts of north-west Australia.

## NORTH WEST – DAMPIER ARCHIPELAGO

The Dampier Archipelago now generally known as Murujuga is a significant rock art province in north-western Australia that documents the Pleistocene–Holocene arid-maritime transition in the cultural landscape (McDonald & Veth 2009). This archipelago of 42 islands has only existed since the mid-Holocene, when the sea rose to its current height. The highly weathered rock art depicts extinct fauna and early styles suggest that occupation and rock art production here was for the same 50 ka period as across the North West Shelf and Pilbara generally. The region today is within the jurisdiction of Murujuga Aboriginal Corporation who co-manage the Murujuga National Park on behalf of the Ngarluma Yinddarbarndi, the Yaburara Mardudhunera and Wonggg-tt-to peoples.

Mulvaney's (2015) seven-phase art sequence predicts that art was produced at Murujuga from the earliest occupation of the region, and a model for Murujuga art production and occupation indices suggests

these different art phases may be correlated with broad environmental events (McDonald 2015). The highly resistant weathering properties of the Dampier Archipelago's geology (Pillans & Fifield 2013), provides a durable canvas for the range of symbolic and social behaviours also being practised across this north-western coastal plain. The estimated one million petroglyphs of the Dampier Archipelago include many thousands of motifs that are highly weathered and include locally extinct fauna (McDonald & Veth 2009). The transition through various styles of production from terrestrial to fresher maritime themes records the change from inland desert range to maritime coastline due to rising sea levels.

Murujuga Rockshelter (MR1) on the Burrup Peninsula offers the oldest evidence for occupation of the then "Murujuga Ranges" (McDonald *et al.* 2018a). The earliest evidence for occupation of this site is dated to the LGM when this range lay over 160 km inland and probably served as one of several Pilbara refugia. In the terminal Pleistocene – early Holocene, likely in tandem with the last stages of sea level rise, the proportion of artefacts manufactured on exotic lithologies declined sharply. We infer a changed foraging range and reduced group territory sizes due to increased demographic packing as the coastline advanced over former territories. Abandonment of MR1 by 7 ka may have resulted from a changing focus to the resources of the increasingly proximal coastline. This site shows how Aboriginal people adapted their Pleistocene procurement strategies in response to significant environmental and landscape changes in Murujuga.

A *Terebralia* midden excavated at Wadjuru Pool on Rosemary Island demonstrates again the exploitation of the extensive mangrove forest resources in the early Holocene (Bradshaw 1995; McDonald & Berry 2017). Ongoing work across the archipelago indicates that this occupation was part of a complex set of human behaviours which included art production and stone structure construction at the end Pleistocene – Early Holocene transition (Figure 2I). At both Boodie Cave and Wadjuru Pool people engaged in broad-spectrum, energy-intensive activities long before the mid-Holocene.

Mangrove habitats and hence species abundance in the North West appear to have declined around 4000 years ago and shell middens reveal that people switched their economic focus to a range of rocky shore, mudflat and sandy beach shellfish (Lorblanchet 1992; Clune & Harrison 2009). This switch is best exemplified by the change of focus from *Terebralia* species to *Anadara granosa*. On the inner island of the Dampier Archipelago, some *Anadara* mounds up to five metres high and >300 m long are as-yet unexcavated but on the basis of sea level history presumably are no older than the mid-Holocene. Most Burrup shell middens indicate mid- to late Holocene exploitation of a range of resources, including land animals such as euro (*Macropus robustus*), rock wallaby (*Petrogale rothschildi*), flying fox (*Pteropus alecto*) and quoll (*Dasyurus hallucatus*), and an extensive range of marine fauna including fish, dugong (*Dugong dugon*), turtles, crabs and birds (Lorblanchet 1992; Vinnicombe 1986).



The sundering of islands off the Australian coast often resulted in their abandonment by people for many millennia (e.g. O'Connor 1999). The outer islands of Murujuga—located 20 km offshore—are potentially distant enough to have made long-term occupation difficult. Rosemary and Enderby Islands, on the outer rim of the archipelago, were cut off by continued rising sea levels by c. 7 ka (Lewis *et al.* 2013). These islands provide an opportunity to explore early Holocene island use and art production—unlike Barrow and the Montebello Islands, where no art has been found. The distance between Rosemary and Enderby Islands and their nearest landfall in the Dampier Archipelago (5 and 3 km, respectively) is minor compared with the c. 50 km to Barrow Island from the current coast. Current systematic survey recording and dating demonstrates a complex signature of symbolic behaviour and archaeological evidence on these outer islands during the Holocene and perhaps only a small hiatus in outer island use.

## NORTH WEST—INLAND PILBARA

Covering some 500 000 km<sup>2</sup> from Barrow Island near the western edge of the continental shelf across some 64 km of Indian Ocean to the remarkable rocky peninsula of Murujuga, the ancient and diverse Pilbara landscape continues inland through vast spinifex plains cut by seasonally flooding river systems and a plateau and escarpment geography of steep ironstone ranges to the borders of the Western Desert. There are now over 20 published Pleistocene archaeological sites in the Pilbara (Morse *et al.* 2014; Marsh *et al.* 2018; McDonald *et al.* 2018a; Slack *et al.* 2017) with other sites known but as yet unpublished (Morse 2009).

The Aboriginal history of the Pilbara is best known in pockets of land investigated in response to mining exploration. Concentrated largely in the rich ironstone Hamersley Range (Morse & White 2009; Slack *et al.* 2018) these sites, excavated rockshelters and caves tell us much about early human occupation and adaptation to an arid and changing landscape. Unlike many other sites discussed here, the typically ironstone-rich acidic sediments of rockshelter sites rarely preserve the organic material that helps our understandings of cultural life or symbolic behaviour. Stone artefacts dominate the archaeological landscape of the Pilbara. Surface stone artefact scatters range from small discrete single flaking events to sites with hundreds of thousands of artefacts extending over tens of hectares. Many sites include quarries, grinding patches, stone arrangements and engraved rock art. All of these contribute much of what we know about how and where Aboriginal people lived, and what they were doing.

Deep in spinifex and ironstone country some 380 km east of Boodie Cave and 100 km south of the modern shoreline, Yurlu Kankala tells the story of early human occupation of this arid inland landscape from 45 ka to middle Holocene times (Morse *et al.* 2014; Reynen *et al.* 2018). The occupation of this site is further testament to the remarkable adaptive capacities of the first Australians and is significant in creating a narrative of adaptation to changing physical and social landscapes before, during and after the last glacial maximum.

Yurlu Kankala is situated on Njama! traditional land. Facing west-northwest, this 280 m<sup>2</sup> rockshelter near the top of the Gorge Range (Figure 2H) commands panoramic views over the surrounding spinifex plains. The area is well watered with a large permanent freshwater pool 500 m to the southwest and other perennial waterholes within three kilometres. Excavated in 2013 (Morse *et al.* 2014) and again in 2014 (Reynen *et al.* 2018), Yurlu Kankala provides a chronological sequence spanning 45 000 years and demonstrates that the occupants of this inland site adapted well to the changing Pilbara landscape. Stone artefacts, hearths, faunal remains, ochre and charcoal throughout the Yurlu Kankala sequence significantly demonstrate continued occupation during the LGM. Grinding material on the site's surface suggests the recent presence of family groups. Six hearths dated between 24 and 18 ka are all associated with stone artefacts and highly fragmented faunal material, predominantly euro, rock wallaby and bandicoot. A small proportion of the bone material is burnt (16.6%) but no evidence of butchering was identified. Stone artefacts throughout the deposit are made on locally abundant raw material, predominately quartz and comprise easily-produced informal, multi-purpose tools. Artefact discard rates peak between 24–23 and 17.6 ka and an increase in the types of tool-stone brought to the cave suggests that it was during this LGM period that the cave was occupied more frequently, or by larger groups of people (Reynen *et al.* 2018).

Unlike the LGM layers where discrete single-use hearths are clearly visible, the post LGM deposit (10–17 ka) is characterised by a high proportion of charcoal and ash and reduced geogenic sedimentation. Although the post-LGM stratigraphic record indicates continued human activity with trampling, fire maintenance, the building of new fires and consequent disturbance and cleaning out of existing hearths, the near absence of stone artefacts in this part of the deposit is surprising. Such a change in the pattern of excavated material suggests that at this time use of the site changed—perhaps as visitors came to undertake short-term task-specific activities that did not require stone tools. Wooden and other organic technologies were among the most adaptive and creative Aboriginal responses to the Australian landscape (Balme & O'Connor 2014), but the acidic deposits of Pilbara rockshelters preserve very little organic material. Yurlu Kankala is no exception and in the context of Pilbara archaeology, the near absence of stone artefacts, with an increased number of hearths in post-LGM Yurlu Kankala deposits, suggests that perhaps people living around the waterholes on the plains close to the rockshelter, armed with a tool kit of perishable materials, such as wooden dishes, spinifex string and other organic technology, were visiting the site to cook or prepare food or make artefacts such as string nets or baskets (Reynen *et al.* 2018).

Recently published data from Watari Jurnti, a cavernous rockshelter some 130 km north-east of Yurlu Kankala in the Cundaline Ridge (Marsh *et al.* 2018), a resource-poor northern Pilbara upland, adds another Pleistocene site to the ever-expanding Pilbara story. First occupied at 45–42 ka, this site provides evidence of continued, albeit occasional or intermittent occupation associated with modifications of stone technology and resource use through the LGM and again in the late

Holocene. Like Yurlu Kankala, organic material at the site is rare and the most recent period of occupation—within the last 1300 years—contains the richest archaeological assemblage. A piece of string made from ‘native [plant] fibre’ was recovered from the most recent part of the deposit, as well as a fragment of baler shell on the floor surface (Marsh *et al.* 2018). This shell material indicates contact between the site’s most recent occupants and the coast some 70 km away. The presence of small pieces of paperback (*Melaleuca* sp.) in Pleistocene layers at this site is also significant. Paperbark is a multi-purpose resource used by Aboriginal people to wrap food into bundles, to make water carriers, as bedding, to swaddle babies, bandages and as medicine (Isaacs 2002). Its repeated occurrence in Waturi Jurnti not only at the time of initial occupation but also in layers dating 31 and 28 ka provides a glimpse of a range of sophisticated behaviours being undertaken by the first Australians, including tasks traditionally associated with women.

The ever-present stone artefacts discarded on surface sites and found in archaeological deposits are key to the Pilbara narrative of small, highly skilled groups of people utilising a wide array of tool-stone, plant and animal resources as they negotiated changing and challenging landscapes and environments. The common presence of grindstone patches and ‘grinding grounds’ sometimes surrounded by extensive panels of engraved art on outcropping granite across many parts of the Pilbara demonstrates the range of technologies—including organic (e.g. spinifex fibre, seed grinding) and inorganic (stone tool sharpening) used by both women and men (Fullagar *et al.* 2017; Hayes 2016; Reynen & Morse 2016). Their perseverance through perhaps the single greatest challenge of all, the Last Glacial Maximum, demonstrates the skilful adaptability of Pilbara Aboriginal people, not just in terms of resource use but in the continued use of critical long-distance social networks (cf. McDonald & Veth 2013a) which connected widely spread and continually moving groups of people. Together, these sites tell us much about the rich cultural lifeways of highly mobile hunter-gatherers, a tradition that continues in the Pilbara today in stories and histories told, and knowledge shared by many Traditional Owner groups.

## WESTERN DESERT

The Western Desert (WD) lies inland of the Pilbara uplands and to the south of the Kimberley. This vast and arid lowland comprises a series of sandy and stony deserts (Veth 1993) covering an enormous proportion of Western Australia. Drainage is internal and fragmented. Amongst the extensive dune fields are numerous subdued ranges, many of which contain permanent water. Although this was one of the last environments to be exploited by Europeans on this continent, archaeological evidence demonstrates that Aboriginal people were inhabiting even this most marginal of landscapes from around 50 ka. Work over the last 30 years with the Martu and Birrilburru custodians of this part of the Western Desert has continued to improve understanding how Australian desert people have used these arid landscapes, uncovering a rich record of evidence for occupation and symbolic behaviour through 50 ka (McDonald 2005; Veth *et al.* 2009; McDonald & Veth 2013a, table 1; McDonald *et al.* 2018b)—as well

as uncovering the interplay between rock art and the *Jukurrpa* (the Dreaming) of those hunter-gatherer peoples who are amongst the last groups to come into contact with settler societies (McDonald & Veth 2013b).

Serpent’s Glen rockshelter, known as Karnatukul to its traditional custodians, is in the Carnarvon Ranges (Katjarra). This rockshelter was the first Pleistocene site identified in the Western Desert (O’Connor *et al.* 1998). Recent excavation (McDonald *et al.* 2018b, 2018c; Figure 2J) has refined the previous occupation sequence and identified earliest occupation from around 50 ka: an LGM occupation signal; a Late Pleistocene–Holocene transition; and a Holocene sequence with defined occupation pulses during the last millennium. The stone artefacts at Karnatukul (Figure 2K) represent a long-term record of artefact use, transport and discard. The site also has a complex painted assemblage, direct-dating of which (McDonald *et al.* 2014) demonstrates that the most recent use of this shelter was as a homebase with industrial quantities of stone tool and wood-working, as well as the extensive decoration of the walls using a local style of pigment art.

The Karnatukul pre-glacial Pleistocene assemblage shows an early preference for high-quality chert that is not found near the site (McDonald *et al.* 2018b). The oldest assemblage includes a retouched ironstone scraper and a backed chert artefact. These hafted artefacts signify early experimentation in this specialised technology in Australia by highly mobile foragers (McDonald *et al.* 2018c).

Artefact discard rates increase slightly during the glacial and terminal Pleistocene period and indicate continued, episodic site visits by highly residentially-mobile groups (McDonald *et al.* 2018b). This is significant, as no LGM dates had been found in the Western Desert before this excavation. The earliest of two distinct pulses of artefact discard during the Holocene is marked by an increase in assemblage diversity, in the mid-Holocene. Grinding technologies appear in the sequence for the first time, demonstrating a variety of animal, plant and seed processing. The toolkit carried by people visiting Karnatukul at this time appears to be designed for a more generalised rather than a specialised subsistence economy.

Occupation during the last millennium at Karnatukul reflects a regional shift in settlement patterns. Artefact discard rates increased substantially. Chert micro-debitage dominates the assemblage, signalling the technological change to specialised tula and backed artefact production. On-site manufacture, maintenance and discard of backed artefacts took place at Karnatukul.

Many aspects of the Karnatukul assemblage resonate with broader regional patterns found across arid inland Australia during the late Holocene. Increased intensity of site occupation, a preference for high-quality stone and increasing conservation strategies are key trends seen at other Western Desert sites. Other WD sites (e.g. Bush Turkey 3, Veth *et al.* 2008; and Kaalpi, Veth *et al.* 2001) show increased residential mobility and logistical provisioning during the last millennia. Karnatukul shows not only a marked increase in use of this locale, but its transition from a satellite site visited episodically, to a more regularly visited and territorially tethered ‘homebase’ where intensive reduction and tool manufacture



took place, and art production similarly showed people's attachment to this place. Western Desert sites demonstrate considerable variability in individual site histories, affirming greater complexity in the use of the arid landscape than previously recognised.

## SOUTH WEST AUSTRALIA

Contrasting with adjoining semi-arid regions and desert further north, the southwestern corner of the continent has a Mediterranean climate: cool, wet winters and warm dry summers, with rainfall increasing southward and westward. The highest rainfall areas (800–1400 mm) are covered by mosaics of wet and dry sclerophyll forest, woodland, heath and wetlands. Devils Lair in the midst of this biodiversity was one of the first sites in Australia to provide evidence of human occupation by 45 ka (Turney *et al.* 2001), and remains one of the country's most important sites for its wealth of stratigraphic, palaeontological and zooarchaeological detail (Balme 2014). The site is emblematic of the archaeological potential of limestone sites along the Western Australian coast.

The region between Capes Leeuwin and Naturaliste (Leeuwin–Naturaliste Region, or LNR) in the extreme southwest is particularly rich, providing evidence for Aboriginal occupation in five caves, including Devils Lair (Balme *et al.* 1978; Dortch 1979; Dortch *et al.* 2014). Tunnel Cave also features hearths and dense archaeological remains deposited over several main occupation episodes between 26 and 8 ka (Figure 2N). Archaeological materials at all cave sites include artefacts made of quartz and fossiliferous chert (sources of this rock appear to have been rendered inaccessible by post-glacial sea levels rise: O'Leary *et al.* 2017; Dortch & Dortch 2019); ochre fragments; emu eggshell fragments; and worked bone, including points at several sites, and three bone beads (Figure 2M) from Devils Lair (Dortch 1979).

Beyond the capes region, Yellabidde Cave, in the Northern Swan Coastal Plain, provides evidence for Pleistocene occupation, with artefacts dated at 28 ka (Monks *et al.* 2016). Another five limestone sites north and south of the LNR were occupied in the last 2–1 ka, a period featuring substantial increases in occupation episodes at open sites as well (Dortch 2004). Despite possible biases due to better preservation of younger material, the possibility of a late Holocene population rise is an important question here (Balme 2014).

Human occupation at Devils Lair is dated from 48 to 12 ka and spans several episodes when the cave entrance closed and then re-opened (Dortch 2004). The lack of archaeological evidence in the three metres of deposit accumulated before 48 ka has been taken to indicate that people first arrived in the region at 48 ka, which following more recent dating work would now be well after the first arrival of humans in Australia (Clarkson *et al.* 2017). This regional interpretation requires much more support, given that Devils Lair provides the only record in the region at this time. Also, the nature of the evidence is complex: the oldest evidence for occupation within the site, as opposed to the re-working of ancient artefacts into levels dated 48 ka, derives from a somewhat younger hearth, at c. 45 ka.

The rich vertebrate remains from the Pleistocene cave sites record environments of the LGM, when sea level was 130 m lower than today and there was an extensive coastal plain west of the present coastline. Analyses of faunal remains and charcoal derived from nearby canopy trees reveal an arid-adapted fauna and woodland/open-forest at this time, changing to closed habitats and karri (*Eucalyptus diversicolor*) from c. 11 000 years ago (Balme 2014; Dortch & Wright 2010; Faith *et al.* 2017). Given land management practices richly recorded in oral and written history (Hallam 2014; Lullfitz *et al.* 2017), these climatic fluctuations over tens of millennia of occupation probably involved changes in land management by Aboriginal populations.

Besides the iconic cave sites, some hundreds of open-air sites have been reported. Although relatively few have been excavated, the dated open-air deposits attest to diverse economic and social behaviours associated with environmental features such as wetlands and coastal woodlands (Dortch & Dortch 2019). Pleistocene archaeological deposits are recorded at Perth (Upper Swan, Helena River, Fiona Stanley Hospital, Rottneest Island (Figure 2L), Minim Cove, Perth Airport; Dortch & Dortch 2019; Pearce & Barbetti 1981; Schwede 1990); in the LNR (Quininup Brook, Dunsborough, Arumvale, Ellenbrook; Dortch 2004); and on the south coast Kalgan Hall (Ferguson 1985) and Cheetup (Smith 1993). Lacking organic remains, the open sites' chief archaeological value is providing stone artefacts in datable contexts indicating the positioning by populations relative to resource zones, generally consistent with historic landscape-use patterns (Dortch & Dortch 2019). The largest and most complex of the Pleistocene open-air sites—at Perth Airport, Helena River, Dunsborough, Kalgan Hall—are near permanent swamps, wetlands or river crossings, places that continued to be used in late Holocene and historic times (cf. Hallam 1987).

The Holocene record suggests the continuation if not the intensification of these patterns. As an example of finely-tuned use of wetland environments, Lake Jasper near Northcliffe formed 3800 years ago, inundating occupation sites, forest trees and former waterholes (Dortch 2002b). The distribution of occupation sites (as interpreted from artefact concentrations in the lake floor), tree trunks in growth position and former swamps, indicates the spatial arrangement of sites in relation to local environments. Additional late Holocene subsistence modes are demonstrated by sites such as fish traps (Dortch 1999; Dortch *et al.* 2006); rock platforms used for processing fish bait and shell scatters (Dortch *et al.* 1984); and trees notched for climbing to catch possums (Meagher 1974).

The region's rich oral and written historic record of past and present landscape use by Nyoongar people is a vital source for generating testable archaeological claims. The Nyoongar language group corresponds approximately to the region's biogeographic boundary and encompasses 13 neighbouring dialect groups, with movements of people documented between each neighbour (Dortch 2002a). Considering the region's historic record, which details early 19<sup>th</sup> century Nyoongar economic and settlement patterns (e.g. Meagher 1974), several adaptations to forests are suggested. Use of forests, including the right to burn vegetation, followed

traditional controls such as inherited and kinship rights and obligations based on places and totem species, tied to religious and spiritual beliefs (Dortch 2002a; Hallam 2002; Lullfitz *et al.* 2017). The longevity of the cultural connection is further confirmed by oral histories of rising post-glacial sea levels (c. 18 000–6000 years ago; Stocker *et al.* 2016) and continuing traditions of plant use (Rusack *et al.* 2011).

Management of woodland, estuarine, and forest resources had subtle impacts that researchers are only beginning to understand. Oral and written records provide a useful starting point (Kelly 1999; Kost 2013; cf. Hallam 2002). Whereas site occupation histories suggests people sometimes relocated sites to deal with post-glacial environmental changes (Ferguson 1985; Dortch *et al.* 2012), there is also evidence that Aboriginal land management influenced habitats (Lullfitz *et al.* 2017). Use of various sites in karri forest suggests people either fired the forest to keep it open or maintained pathways (Dortch 2005; Dortch *et al.* 2010). Marked changes in abundance of marsupials, suggesting changes in habitat, are correlated with the posited population changes at c. 1 ka, and following European disruption of Aboriginal burning c. 150–100 years ago (Dortch *et al.* 2014; Faith *et al.* 2017; Monks 2018).

The material culture that survives indicates connections with other regions and continuities through time. Backed stone artefacts appear from c. 4000 BP, in accordance with their continental proliferation (Dortch *et al.* 2012). Bone points were still being made in recent decades (Bird & Beeck 1988). Rock art is not widespread in the region, ostensibly due to a lack of suitable rock surfaces. One art site in the far South West suggests motifs forms in common with early art from other regions, yet was executed on what appears to be a Late Holocene rock formation (Gunn *et al.* 2011).

Historically, as shown in linguistic and genetic evidence, Nyoongar people had long-distance connections with neighbouring groups (Malaspinas *et al.* 2016). Archaeological evidence for these connections may include ochres from the South West in other regions, putatively traded over long distances (Hallam 2014). Recent advances in ochre-sourcing (Scadding *et al.* 2015) suggest potential for identifying long-distance exchange of archaeological ochres. As with the internal boundaries between dialect groups, the boundaries between language regions were permeable (Dortch 2002a). Like the peoples of other regions discussed in this paper, this record of connection to the region and with neighbouring groups may explain the persistence of occupation by the Nyoongar people for nearly 50 000 years.

## DISCUSSION

This overview of the archaeology of the first peoples of Western Australia identifies many different cultural groups each with distinct regional histories. Despite this heterogeneity, a series of observations are common to all four major regions discussed here:

- At a broad scale, there is continuous occupation from 50 ka demonstrated by at least one site in each region. There is little reason to suppose that large regions were entirely abandoned after initial

colonisation except for the possible exception of sandridge deserts at the LGM (Veth 1993), and, as we suggest below, genetic and archaeological records suggest continuity within regions.

- At the available resolution it is not possible to establish pathways or rates of colonisation. Although colonisation was most likely from the north, our sample is too small to determine any further details from the chronologies available or by current dating methods.
- Occupation persists at certain sites or localities in each region through the LGM, especially in the high rainfall Kimberley and South West and in the inland ranges of the Pilbara.
- Aboriginal populations appear to have increased in the Holocene, although archaeological and genomic estimates are still crude, and it is not possible to identify a consistent demographic pulse across all regions.
- Aboriginal groups formed extensive social networks within and between regions as shown by the distribution and stylistic connection of regional art bodies in all but the South West.
- Technological innovations once thought to be confined to the Holocene—e.g. ground stone technology; backed blades; hafted implements—appear in the Pleistocene, as early as 40 ka in some cases.
- All groups engaged in art production, or at least used ochre for art or ornamentation, and produced personal ornaments in the form of shell or bone beads, from the earliest periods of occupation.
- All groups exploited localised resources, including marine foods and shellfish in coastal regions, indicating familiarity with different environments from an early point in occupation history.

All of these traits are evident in the Pleistocene when overall population may have been relatively low (Malaspinas *et al.* 2016; Veth *et al.* 2011; Williams *et al.* 2015). As evidence for how regional populations organised themselves at this time is limited, it is difficult to identify any particular social structure, much less societies analogous to the ethnographically recorded, dense populations of the last few centuries. However, based on ethnographic examples of sparse populations worldwide, the putative lower population density would almost certainly have promoted an even greater extension of long-range social networks in order to maintain viable social groups. These extended networks are consistent with the appearance of materials used for ornamentation in the Kimberley, North West and South West, such as marine shells and ochre, suggesting transport over considerable distances in the Pleistocene, most likely through inter-group exchange, as the distances are too great for the annual round of a single group. Interpretation of the number of dated occupation layers in successive periods as a proxy for population, while disputed, suggests on the whole that Pleistocene populations were small (Williams *et al.* 2015). Nevertheless, broad genetic estimates of effective population size (the minimum population required to sustain the observed genetic diversity) suggest that



regional populations rose relatively quickly after 40 ka, becoming differentiated by 30 ka, dipped at the LGM, and rose again with post-glacial amelioration well before the late Holocene (Malaspinas *et al.* 2016). The genetic differentiation may well have correlated with cultural differentiation; the relatively early changes in population size suggest groups had adapted early to Pleistocene conditions. If taphonomic corrections are valid, late Holocene spikes in dated occupation layers are not explained by better preservation, and could represent real population rise (Williams *et al.* 2015).

Use of broad suites of resources from almost every ecosystem available is a trait of many foraging peoples and of all Australian societies in ethnographically recorded times. The limitations of most Western Australian environments go some way to explaining the use of diverse environmental zones including marine and coastal environments, montane deserts, and nearly every environment apart from sand-ridge deserts during full glacial aridity (Veth 1993). Broad foraging modes in each region would have required considerable familiarity with landscapes and capacity to transmit knowledge through generations, which in turn implies continuity in regions—all facilitated by attachment to place, which is renowned among Aboriginal people today.

Land management can be claimed in locations where ethnographic information allows the construction of testable hypotheses. Such models can be developed in all regions reviewed here: existing ones are well known in the anthropological and historical literature for the Western Desert and South West (Bird *et al.* 2018; Hallam 2014). It is highly likely that earlier generations of Aboriginal people had the technical and organisational capacity to manage many ecosystems. However, archaeological evidence supporting these views remains to be acquired and investigated.

The emerging evidence for long-term continuities in archaeological and genetic records in Western Australia as a whole implies long-term intimacy with ecosystems and detailed knowledge of land and seascapes. The complex land-management practices observed during and after each region's European colonisation imply technical expertise, social controls, and inherited responsibilities and affiliations to land. These practices would seem to require a substantial development period—nonetheless achievable well within in the long period reviewed here, if not even in the first few millennia of occupation. However the process of successful landscape learning is for now shrouded in uncertainty, given that impacts of hunter-gatherer colonisation events are highly disputed on all continents. The Western Australian records reviewed here, particularly from limestone caves and other well-stratified deposits, seem to offer considerable potential to explore landscape learning in the earliest millennia of Aboriginal occupation.

## CONCLUSION

The record of human occupation of Western Australia is characterised by creation and persistence of regional cultural identities, associated with dynamic, social responses to environmental challenges. Among these

responses, technological innovation, symbolic behaviour and development of a wide resource base were critical factors in the history of human adaptation to fifty millennia of change. The need to adapt to local environments—landscape learning—would have been balanced with the necessity for social interaction over extensive areas with shared resources. The early solution in many regions was the development of a common symbolic vocabulary enabling mutual comprehension between regionally-differentiated social groups across the continent. Further possible tensions would have been resolved through the historically documented, mutually recognised affiliations to place, and long-distance networking between knowledge-holders of stories and rituals concerning sites. More recently, social groups became increasingly territorially embedded in place, distinct style boundaries developed with easily recognisable and iconic rock-art styles (e.g. Wanjin art in the Kimberley) in each of the regions discussed. Australia's persistent societies have long genealogies, genetically, linguistically and culturally. We suggest the Songlines and shared Dreamings of the modern era have an ancient history in connecting past communities of Aboriginal societies.

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